Investigations in the Okavango Delta Using EO-1 Data

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A series of investigations that relate to the performance of EO-1 instruments have centered on the seasonal flooding of the Okavango Delta in northwestern Botswana. The extreme inaccessibility of the area makes it an ideal candidate for the use of remote sensing to map the annual flooding and land cover in the region (Figure 1)

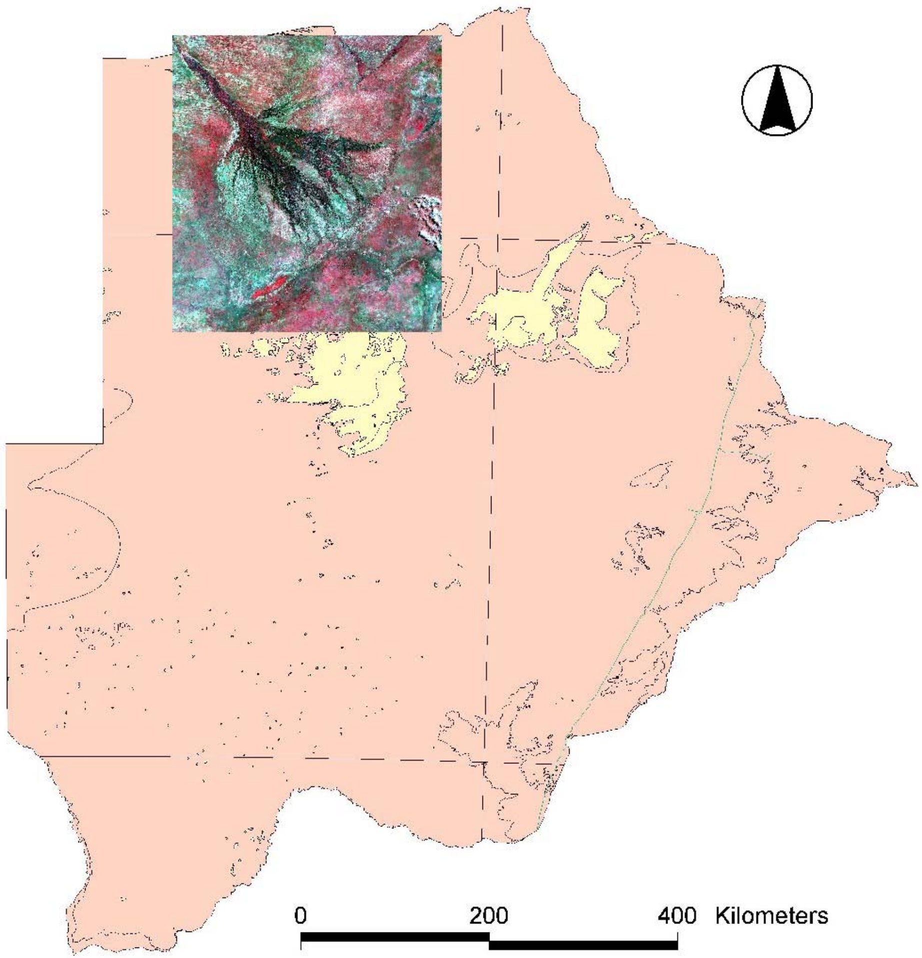


Figure 1. Okavango Delta of Botswana as seen in Landsat ETM+ data.

The Okavango Delta is the world's largest inland delta. It is fed by the Okavango River, which originates in Angola's western highlands (Figure 2). The catchment area for the Okavango River lies in three countries (Angola, Namibia, and Botswana, although the drainage flow from Namibia is completely dry) and has a total area of approximately 325,000 km^2. The Delta extends 250 km along its radial axis and extends over 22,000 km^2 in area. The floodwaters require approximately nine months to travel from their source in Angola to the bottom of the Delta because of the extremely low topographic relief. Interestingly, the annual flooding occurs during the area's dry season (June through August) when most days are cloud-free and suitable for acquiring data from optical sensors such as MODIS, Landsat TM, and EO-1 ALI and Hyperion.

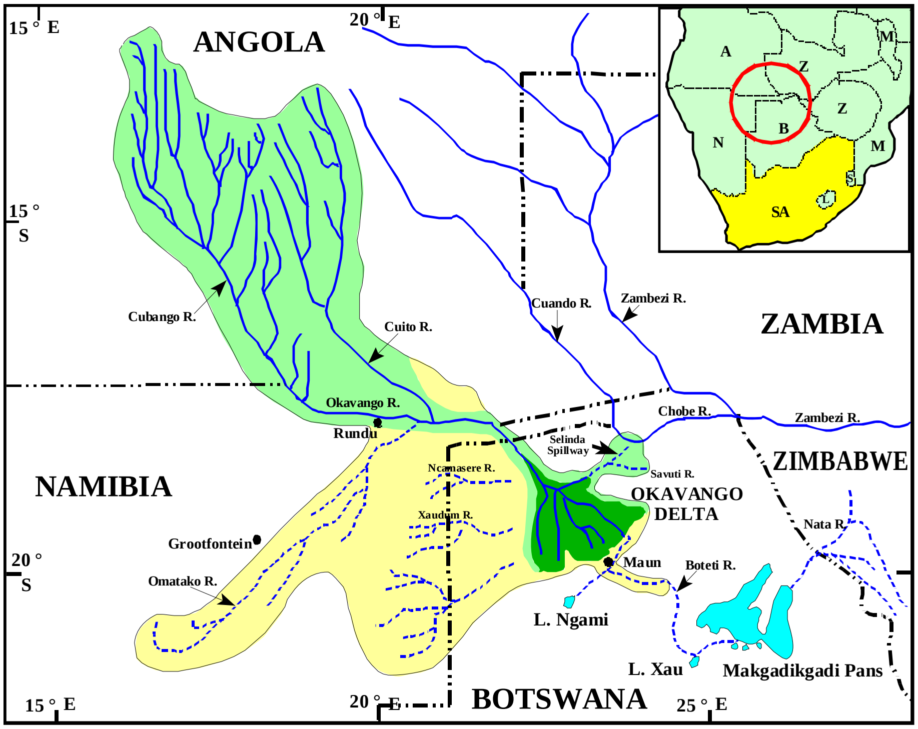


Figure 2. Okavango Catchment

A field campaign, conducted in March 2001 by the University of Texas Center for Space Research (CSR) in conjunction with the University of Botswana Harry Oppenheimer Okavango Research Center (HOORC), focused on a portion of the Delta known as Chief's Island (Figure 3). The land cover in this area includes swamplands, grasslands that are seasonally flooded, as well as woodlands that are not flood prone. Seasonal swamps, which cover ~4,700 km^2, are areas of grasslands that flood annually. Occasional swamps flood in one-to-ten-year intervals rather than annually. These areas occupy ~11,000 km^2 and are comprised primarily of grasslands, but also include shrubs and small woody plants. A focus of this study was to characterize the annual flooding by mapping the spatial patterns within the lower Delta as well as to identify small-scale responses of vegetation. The interannual flow variability in the Delta is primarily due to alluvial processes but appears to be a function of annual variability in vegetation within the floodplain, hippo activity and burning practices, as well as of the amount of annual rainfall. The spatial and temporal variation of flooding of these channels is important for managing the competing uses of this scarce resource.

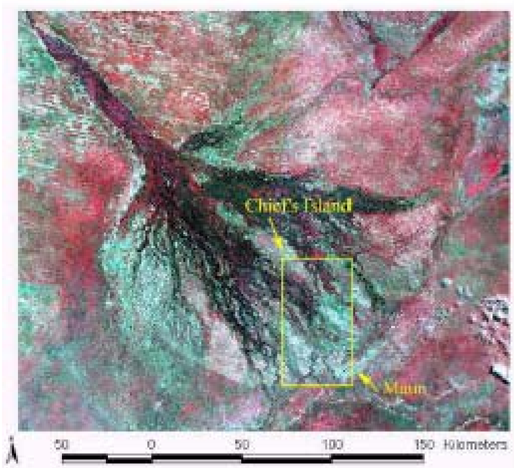


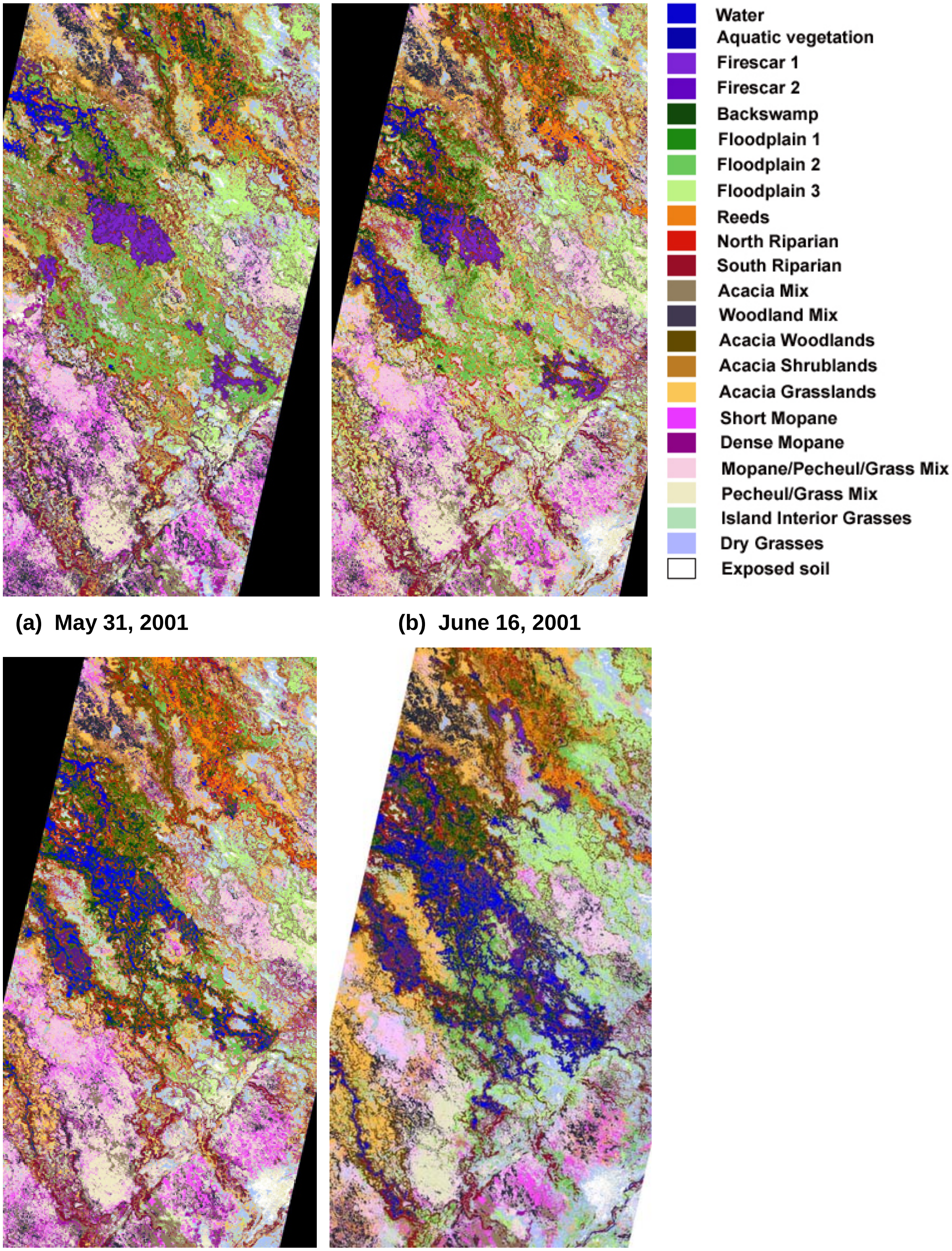
Figure 3. ALI coverage of Chief's Island and the lower Okavango Delta

The investigations used data acquired by the Advanced Land Imager (ALI) on five dates: May 31, June 16, July 11, and August 19, 2001 (Figure 4) and September 16, 2002. The study focused on the following:

- Characterizing vegetation responses to flooding and seasonal variations in spectral responses of vegetation,
- Determining the spectral response of riparian forest to seasonal flooding as a potential indicator of increased evapotranspiration rate in the Delta, and
- Comparing the improved capabilities of the ALI multispectral bands relative to the Landsat Enhanced Thematic Mapper (ETM+) for discriminating land cover types.

Further analyses, using only imagery acquired on May 31, investigated the following:

- Potential improvement of hyperspectral data from Hyperion for discriminating land cover,
- Viability of configuring application-specific multispectral sensors from hyperspectral sensors,
- Capability of new algorithms for classifying complex land cover environments, and
- Methods for mitigating artifacts in ALI and Hyperion data and the impact of these artifacts on classification results.



(a) May 31, 2001 **(b) June 16, 2001**

(c) July 11, 2001 **(d) August 19, 2001**

Figure 4. ALI 2001 Classified Data.

A Bayesian Pairwise Classifier (BPC) algorithm with feature selection was used to classify land cover into the 23 categories listed in Figure 4. The feature selection method provided one means of investigating the contribution of the new bands in ALI relative to those of ETM+ and typically performed well when classes were difficult to discriminate due to similar spectral signatures. Overall classification accuracies for ALI were consistently higher (~83%) compared to ETM+ (~68%), and results were also superior in terms of visual, qualitative evaluation. This improvement in the classification is attributed to the higher signal-to-noise ratio (SNR) and the increased dynamic range of the ALI data. ALI also yielded improved fine scale mapping of the flood channels relative to ETM+.

This spatial variability of the flooding patterns and its impact on biota of the Delta is not well understood, but is critical for management of the ecosystem. The variability in inter-annual variation in flood patterns is clearly demonstrated in Figure 5 that contains corresponding flood cover from 2001 and 2002. The total area of flooded lands in 2001 was 257 km^2, whereas in 2002, only 200 km^2 was flooded in this portion of the Delta.

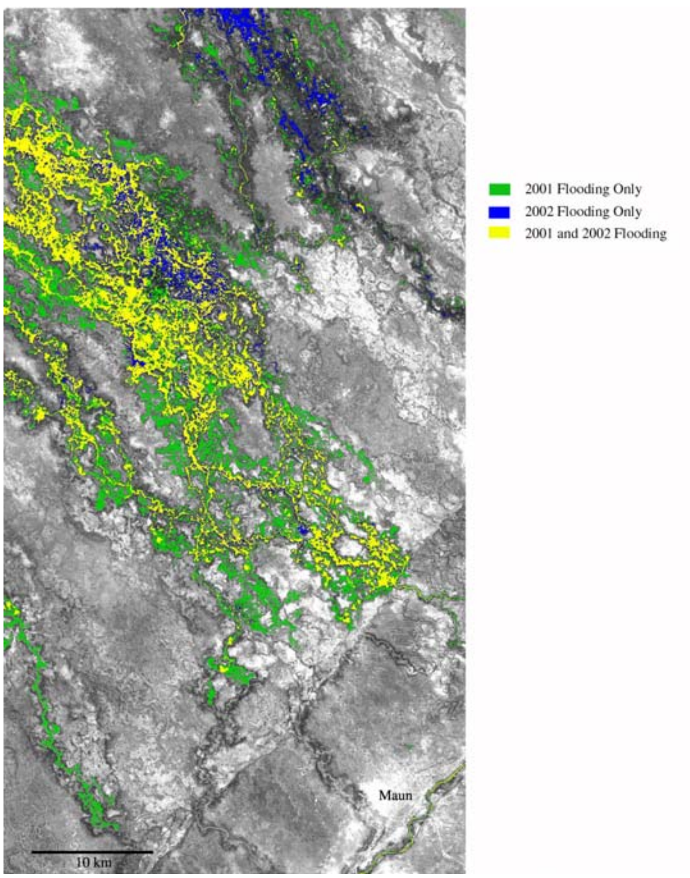


Figure 5. Flood cover for lower Delta in 2001 and 2002.

EO-1 also provided the first high-resolution sequence of remotely sensed data for studying the response of woodland species including the riparian forest. Riparian forest is thought to be a potential contributor to the high evapotranspiration rate in the Okavango. Figure 6 compares the spectral responses of many woodland species in May 31, 2001 and July 11, 2001. Although the woodland classes do not exhibit greening, there is a response in the short-wave infrared (SWIR) of shrubs, short mopane, and woodland mix. While the signatures for some classes are not well understood, the increase in the reflectance of the short mopane class in the July 11 is due to the fact that the short mopane has begun to drop its leaves by mid-July and the soil background is now showing through.

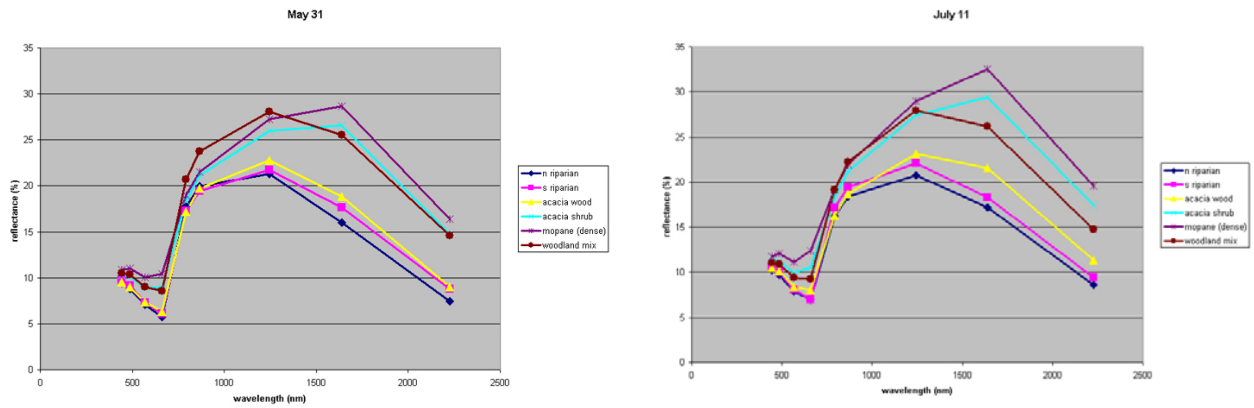


Figure 6. Spectral signatures May 31, 2001 woodland classes (left) and July 11, 2001 woodland classes.

The improved resolution and increased SNR of the ALI panchromatic band relative to that of ETM+ is well demonstrated in Figure 7 which contains scenes over the town of Maun acquired on August 12 and August 19, 2001 respectively. It also helped delineate boundaries of land cover types and discrimination of boundaries of trona islands located in the seasonal swamps (Figure 8).

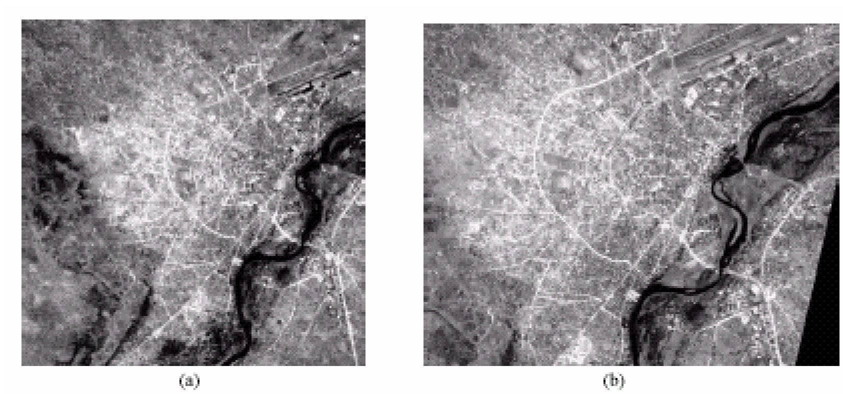


Figure 7. Panchromatic images from ETM+ (a) and ALI (b).

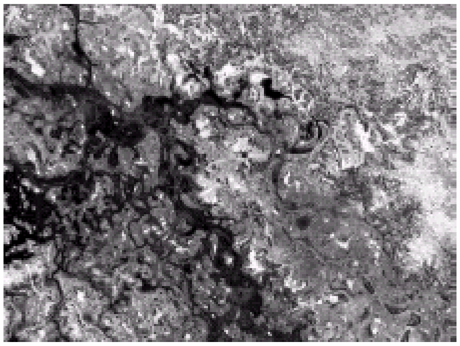


Figure 8. ALI panchromatic image of trona islands in seasonal swamp.

In addition to mapping the flood extent in the lower delta, ALI and Hyperion data were compared on the May 31 acquisition to determine whether improved accuracies would be achieved using the hyperspectral sensor. The May 31 data were acquired at the onset of the flooding season; thus the vegetation within the Hyperion swath was more diverse and less inundated than later in the year. To date, this type of direct comparison between multispectral and hyperspectral sensors has not been possible as hyperspectral sensors prior to the EO-1 have been flown on airborne platforms flown at lower altitudes, and acquisitions have not been simultaneous. Overall, classification accuracies obtained from analysis of Hyperion data (~73%) were slightly lower than those obtained using ALI (~82%), although discrimination of some classes that exhibited distinct fine feature signatures was superior to that of ALI. Of particular note was the over- classification of the riparian category in ALI results since the riparian ecotone is thought to play a critical role in the evapotranspiration process in the Delta. Hyperion data provided improved discrimination of these classes (see Figure 9). The unexpected overall lack of improvement from Hyperion was attributed to problems with uncompensated streaking in the hyperspectral data and to signatures of mixed classes, for which classification cannot benefit from the narrow hyperspectral bands. Classification accuracies using synthesized ALI data (~75%) generated from Hyperion bands were comparable to those for data acquired from the original ALI bands in terms of classification, thus lending credibility to the practice of creating "on the fly" multispectral sensors from hyperspectral data.

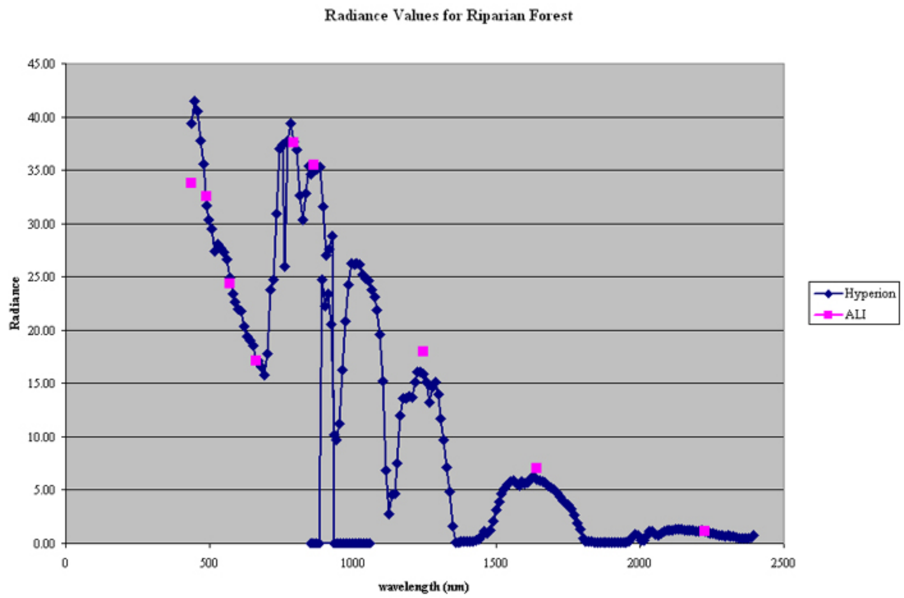


Figure 9. Comparison of Spectral Information between ALI and Hyperion.

Ongoing research is focusing on analysis of data acquired during the 2002 flooding season and on field verification of land cover mapping. Collaborative research to improve digital elevation models and incorporate them into the analysis is also underway. Finally, results obtained from ALI and ETM+ are being related to MODIS data for up scaling results and providing a higher temporal resolution capability for monitoring the ecology of the Delta region.